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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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# PRESSURE DISTRIBUTION ON THE NOSE OF AN AIRSHIP IN CIRCLING FLIGHT.

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In recent tests conducted by the National Advisory Committee for Aeronautics at the Hampton Roads Naval Base on the pressures occurring on the envelope and control surfaces of the Naval airship C-7, it was noted that the pressures on the nose of the airship, while flying in level circling flight, were symmetrically distributed. Such a distribution can only occur when the nose of the airship is pointed directly into the wind, and to accomplish this in circling flight the axis of the airship must then be parallel to the direction of motion of the nose. That this condition was present in the C-7 tests was later verified by a series of photographs taken of the airship in circling flight by means of a camera obscura. The question was then raised as to whether the same conditions occur generally on all airships in circling flight and it is with this problem that this paper deals.

In considering the lateral forces acting on an airship in circling flight, we find that there are but two of any magnitude. The first is the centrifugal force

$$F = \text{Volume} \times \rho \; \frac{V^2}{R} \qquad (1)$$

and since the hull displaces air equal in weight to the weight of the airship this force acts at the center of mass of the displaced air, the center of buoyancy, and also passes through the center of the flight path circle. R is the radius of the circle and V the velocity of the center of bucyancy.

An airship hull without fins is statically unstable in yaw, and for equilibrium in flight the resulting moment must be balanced by one of the opposite sense produced by a force acting on the vertical fins. This force has been computed to be (Reference 1)

$$F = \text{Volume} \times \frac{\rho V^2}{2a} (K_2 - K_1) \sin 2\varphi \tag{2}$$

where $K_2$ and $K_1$ are constants expressing the ratio of transverse and longitudinal volume of apparent mass to the displaced volume for airships with different fineness ratios, a is the distance from the center of buoyancy to the point of application of the resultant transverse fin force, and $\varphi$ is the angle between the axis of the airship and the direction of motion of the center of buoyancy.

The above expression was derived from a consideration of the forces caused by motion in a perfect fluid but gives results in agreement with model tests within a very small error. A more complete discussion may be found in N.A.C.A. Report No. 184; "The Aerodynamic Forces on Airship Hulls," by Dr. Max M. Munk.

Since these forces act in opposite directions and are the only transverse forces of any magnitude for equilibrium in flight they must be equal and it follows

$$\sin 2\varphi = \frac{2a}{R(K_2 - K_1)} \tag{3}$$

Referring to Fig. 1, if we call $\theta$ the angle which the axis of the airship forms with the direction of motion of the nose, we can establish by means of a simple trigonometric relation that

$$\cot \theta = \frac{R \cos \varphi}{b - R \sin \varphi} \tag{4}$$

If we substitute in the above expression the value for $\cos \varphi$ which may be found from expression (3), we have

$$\cot \theta = \frac{a}{\sin \varphi \ (K_2 - K_1) \ (b - R \sin \varphi)} \tag{5}$$

and an approximation of calling

$$\sin \varphi = \frac{a}{R(K_2 - K_1)} \tag{6}$$

from expression (3) introduces but a slight error that may be neglected. Substituting the last expression in (5) gives us in its final form:

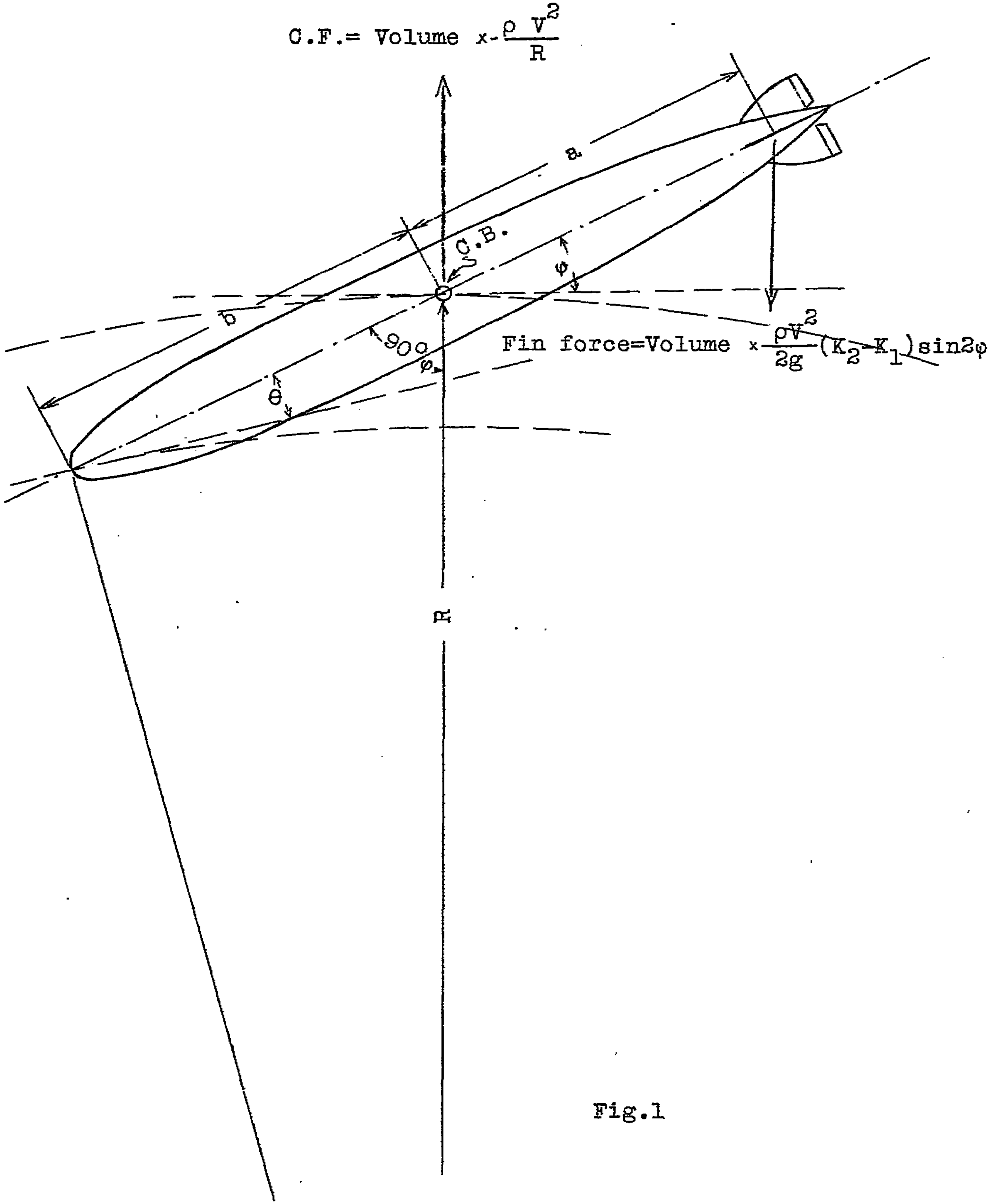
$$\cot \theta = \frac{R}{b - \dfrac{a}{(K_2 - K_1)}} \tag{7}$$

The factor $(K_2 - K_1)$ is always close to unity and the difference between $b$ and $a$ in existing airships is seldom more than 2 per cent of the length of the airship, while the radius $R$ of the circle of flight path is always greater than three times the length even in the sharpest turns. From this it may be seen that the value of $\cot \theta$ is so large that $\theta$ cannot be but a few minutes even in the sharpest turns. For airships with a large fineness ratio, that is, a fineness ratio from 8 to 10, the denominator becomes even smaller and the angle may be said to be virtually zero.

It appears, therefore, that airships flying in a constant, level, circling flight path will generally head very closely into the wind and any deviation will be so slight that the distribution of pressure over the nose will be but slightly, if at all, changed from a symmetrical distribution.

Reference

1. Max M. Munk: The Aerodynamic Forces on Airship Hulls. N.A.C.A. Technical Report No. 184 - 1924.



C.F.= Volume $\times \frac{\rho V^2}{R}$
a
C.B.
b
φ
90°
φ
θ
R
Fin force=Volume $\times \frac{\rho V^2}{2g}(K_2-K_1)\sin 2\varphi$


Fig.1